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Federal Water Pollution Control Administration
Cincinnati, Ohio

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FWPCA PRESENTATIONS

ORSANCO ENGINEERING COMMITTEE

SEVENTIETH MEETING
TERRACE HILTON HOTEL
CINCINNATI, OHIO

SEPTEMBER 10, 1969

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OHIO BASIN REGION
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
UNITED STATES DEPARTMENT OF THE INTERIOR
CINCINNATI, OHIO

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ACCEPTABLE WATER QUALITY IN MIXING AREAS

Kenneth M. Mackenthun

As stated in the National Technical Advisory Committee Report, and to protect water quality, mixing areas must not be used for, or considered as, a substitute for waste treatment, or as an extension of, or substitute for a waste treatment facility. Mixing should be accomplished as quickly as possible through the use of devices which ensure that the waste is mixed with the allocated dilution water in the smallest possible area. At the border of the mixing area, water quality must meet water quality standards.

Mixing zones should not be permitted where serious damage may be done to a recognized aquatic resource. The location of mixing zones should be determined on a case-by-case agreement between the Federal Water Pollution Control Administration and the involved State government and/or interstate compact.

Where mixing zones are allowed, the following are recommended:

1. As a guideline, the maximum distance of the mixing zone in any direction should not exceed that obtained by multiplying the square root of the discharged number of million gallons per day times 200 feet (i.e., 25 mgd = $\sqrt{25}$ x 200 = 1,000 feet); and in no case exceed 3/4 mile;

2. Mixing zones for single or cumulative discharges should be limited to 25 per cent of the cross-sectional stream area width, or volume of flow; when density differences between waste waters and receiving water produce stratification the stratified layer shall not extend beyond 25 per cent of the width of the stream;

3. At no place in the mixing zone should the 96-hour TL_m to aquatic life be exceeded;

4. Mixing areas shall be:

   Free from substances attributable to municipal, industrial or other discharges that will settle to form putrescent or otherwise objectionable sludge deposits;

   Free from floating debris, oil, scum, and other floating materials or other discharges in amounts sufficient to be unsightly or deleterious;

Free from discharged materials that produce color, odor, or other conditions in such degree as to create a nuisance;

Free from substances and conditions or combinations thereof in concentrations that produce undesirable aquatic life.

WATER QUALITY STANDARDS-

GUIDELINES ON THERMAL POLLUTION CONTROL

Thomas J. Powers, III

INTRODUCTION

To establish adequate guidelines on thermal pollution control it is necessary to recognize that heat is a pollutant. Thermal electric power plants are by far the largest user of cooling water. To assure compliance with water quality standards, discharge of heated water must be controlled. The guidelines for establishing water quality standards for interstate waters under the Water Quality Act 1965, Public Law 89-234, May 1966, clearly state that such control shall be required of cooling water discharges. Current policy specifically puts the burden of the proof on any potential polluter to prove his case to the State pollution control agency and the Secretary of the Interior.

THE POWER INDUSTRY

A summary of industrial water use in 1964 by investor-owned thermal electric power plants in the United States is presented in Table 1.

In 1964, the total cooling and condensing water used by thermal electric plants amounted to more than 78 per cent of the total used by all industry. Intake water for the power industry amounted to roughly 70 per cent of the industrial total; about 77 per cent of the total industrial water discharge was from thermal electric power plants.

By 1970, thermal electric power plants will need a total of 57,000 bgy for cooling water. This increase in water use could be accompanied by an increase in thermal pollution from waste heat which is not easily recovered or utilized at the present time. Other pollutants may include: fly and bottom ash (nitrogen and phosphorous compounds), lime, calcium, and aluminum, potassium, and sulfates.

The power industry, like other industries has a responsibility for pollution control. The quantity of water utilized by an

Table 1. Industrial and Investor Owned Thermal Electric Plant Water Intake and Discharge, 1964

[Source: 1963, census of manufacturers, water use in manufacturing (7) and water resources activities in the United States--electric power in relation to the Nation's water resources (9)]

SIC	Industrial Group	Water Intake (bgy)		Water Discharged (bgy)
		Cooling and Condensing	Total	
20	Food and kindred products	392	760	688
22	Textile mill products	24	147	134
24	Lumber and wood products	71	151	123
26	Paper and allied products	607	2,071	1,942
28	Chemicals and allied products	3,120	3,886	3,659
29	Petroleum and coal products	1,212	1,399	1,318
31	Leather and leather products	1	16	15
33	Primary metal industry	3,387	4,578	4,312
	Subtotal---------	8,814	13,008	12,191
	Other industries-	571	1,039	968
	Total industry---	9,385	14,047	13,159
	Thermal electric plants	34,849	34,849	34,781
	Total----------	44,234	48,896	44,940

Note: Summarized from "Report of the Committee on Water Quality Criteria," page 188, Report of the National Technical Advisory Committee to the Secretary of the Interior, April 1, 1968.

industry is important, but the quantity of pollutants released to the environment is most critical. If the pollutants cause damage to the environment, they must be controlled to satisfactory levels that will protect the environment and prevent degradation.

HEAT IS A POLLUTANT

Waste heat, when released to the water environment, may become a pollutant more dangerous to our Nation's waterways than the more common forms of wastes. Thermal pollution has been defined as man-caused, deleterious changes in the normal temperature of water. The changes can be either an increase or a decrease in normal or ambient water temperature. The change is deleterious when specific water use criteria is impaired. A temperature above 85 degrees F. produces deleterious effects in public water supplies, bathing and recreational areas, and some warm water aquatic life. In defining these thermal impairments, we must know the specific water use involved and the effect of heat on a well-rounded warm water biota. The species affected by adverse temperature levels and conditions must also be identified.

GUIDELINE NUMBER ONE-

THE ANTI-DEGRADATION STATEMENT

Guideline No. 1-"Water quality standards should be designed to enhance the quality of water. If it is impossible to provide for prompt improvement in water quality when initial standards are set, the standards should be designed to prevent any increase in pollution. In no case will standards providing for less than existing water quality be acceptable."

The acceptability of standards providing for less than existing quality can be determined by two questions:

1. Are all existing water uses being preserved?

2. Are waste discharges which are amenable to treatment or control being treated or controlled?

If the answers to those questions are "yes," the standards normally would be acceptable. In the present case, existing water uses would not be preserved if we were to eliminate several species which inhabit the Ohio River. We hope to indicate today that waste-water discharges from thermal power plants are amenable to treatment or control.

GUIDELINE NUMBER SEVEN-

COOLING WATER DISCHARGES

Guideline No. 7-"The plan should include consideration of all relevant pollutional sources such as municipal and industrial wastes, cooling water discharges, irrigation return flows, and combined sewer overflows."

Since cooling water discharges constitute a relevant pollutional source, consideration should be given to the control of these discharges. After discharges each waste heat source should be considered individually to determine its impact on the environment.

GUIDELINE NUMBER EIGHT-

WASTES AMENABLE TO TREATMENT OR CONTROL

Guideline No. 8-"No standard will be approved which allows any wastes amenable to treatment or control to be discharged into any interstate water without treatment or control regardless of the water quality criteria and the water use or the uses adopted. Further, no standard will be approved which does not require all wastes, prior to discharge into any interstate water, to receive the best practicable treatment or control unless it can be demonstrated that a lesser degree of treatment or control will provide for water quality enhancement commensurate with proposed present and future uses."

In general, this guideline requires secondary waste treatment by municipalities and an equivalent high degree of waste treatment or control by industries. Adequate treatment for industrial wastes can be handled on an industry-by-industry basis. The best practicable treatment or control for a thermal power plant may mean cooling towers, cooling ponds, or other cooling devices. We are not endorsing cooling towers, per se, to solve the cooling water problem. The degree of treatment required of a power installation must be that required to assure the 96-hour TL_m value within the mixing zone of the biota normally associated with the particular geographical area in question. For thermal wastes, any lesser degree of treatment than the best practicable will be accepted only if the lesser degree will not cause degradation.

If we are serious about maintaining water quality we must be serious about waste treatment, control and/or preventive measures. Application of waste treatment technology after waters have become polluted is generally not effective and is certainly not in keeping with the preventative approach called for by water quality standards. This guideline puts the burden of proof on any potential polluter to prove his case to State pollution control agency and the Secretary of the Interior.

SUMMARY

If we are truly dedicated to the enhancement of water quality this would mean a reduction of the present total heat load where heat is already damaging. Instead of a justification for maintaining or increasing the waste heat released to the water environment, perhaps it would be well to consider policies which would bring about stronger emphasis on the total heat load reduction in the Ohio Valley.

The real issue here today is not whether we need thermal pollution control or even if it is feasible at this time, but rather whether we are to permit extinction of the Sauger (jack salmon) on the Ohio River. Should an attempt be made to preserve this species for the Ohio Valley sportsman? The history of temperature on the Ohio indicates that the waste heat loads and other conditions have gradually heated the Ohio until we are now at the threshold tolerance level. The decision must be made. It would appear that the elimination of the Sauger would mean further degradation. This further deterioration of our waterways is not in line with the Water Quality Act of 1965, nor is it consistent with the current policy of the present Administration. It is recommended that the following policy be adopted:

1. The Ohio River shall be maintained as a well-rounded warm water aquatic life habitat.

2. The temperatures considered typical for the period 1962 through 1969 shall be utilized to evaluate the current temperature data and future temperature on the Ohio River.

3. The Sauger species (jack salmon) shall be used as the indicator for progress in thermal pollution control on the Ohio River.

4. The anti-degradation policy shall be utilized to the utmost to preserve the Ohio's biota.

5. For the tributaries to the Ohio, specific temperature recommendations should be made which are consistent with the normal biota.

TEMPERATURE EFFECTS ON DISSOLVED OXYGEN-

WHITE RIVER

Stanley M. Smith

While sanitary engineers are aware of the effect of high water temperature on the oxygen resources of a stream, the magnitude or degree to which the resources are affected is sometimes overlooked. This is particularly true in an oxygen-sag situation since high temperature not only reduces dissolved oxygen saturation but also increases the rate of deoxygenation of a stream.

The effect of temperature in an oxygen-sag situation is illustrated by data obtained from a DO-CAL computer program that has been used for the West Fork White River through the critical reach below Indianapolis, Indiana. This computer program is set up on the basis of adding water, as from an upstream reservoir or so-called "magic bucket," to a stream and solving a series of oxygen-sag problems until it is determined that an established dissolved oxygen objective has been met. In other words, the computer program starts out with a set flow in the stream and, if this flow is insufficient to meet the dissolved oxygen (D.O.) objective, it calls for more and more water until the objective is finally met. Basic variables that can be placed in the program in addition to the D.O. objective are temprature and wastewater treatment efficiency. Thus, the output shows the flow that is required to meet certain D.O. objectives at different temperatures and treatment efficiencies.

Table 1 shows data for a D.O. objective of 4.0 mg/l and Table 2 gives similar data for an objective of 5.0 mg/l. The flows listed are those just above the Harding Street Plant (S.T.P. No. 1) in Indianapolis. Another large plant (the Southport Road plant) is located about 6.2 miles downstream; however, the effect of both plants are taken into consideration in the problem. In both tables, the data represent calculations of future flow needs in the Indianapolis area under assumed conditions of wastewater flow and quality characteristics.

TABLE 1

REQUIRED FLOW - AT GIVEN TEMPERATURES, CFS

(Minimum D.O. Objective - 4.0 mg/l)

Treatment Efficiency, %	68°F	80.6°F	86°F	91.4°F
92	280	664	919	1,216
95	235	324	370	585
98	185	256	292	339

TABLE 2

REQUIRED FLOW - AT GIVEN TEMPERATURES, CFS

(Minimum D.O. Objective - 5.0 mg/l)

Treatment Efficiency, %	68°F	80.6°F	86°F	91.4°F
92	529	1,282	1,748	2,422
95	351	693	1,063	1,552
98	299	425	502	606

The above data show that temperature loading has an effect similar to a BOD loading in that either a higher treatment level or a greater amount of flow is necessary to maintain a specified dissolved oxygen level. For example, for a temperature increase from 80.6°F (27°C) to 86°F (30°C) with a D.O. objective of 5.0 mg/l and 95 per cent treatment efficiency, flow needs are increased by 470 cfs from 693 to 1,063 cfs or approximately 53 per cent.

The temperature effect can also be illustrated by graphing the data so that estimated minimum dissolved oxygen levels can be obtained for a specified treatment efficiency under different temperature conditions. The following data were obtained in this manner.

TABLE 3

MINIMUM D.O. - AT GIVEN TEMPERATURES, mg/l

(Treatment Efficiency 92%)

Flow in Stream above Harding St. Plant, cfs	68°F	80.6°F	86°F	91.4°F
500	4.9	3.6	3.2	2.6
1000	5.8	4.6	4.2	3.6
1500	---	5.2	4.8	4.3

Much of the input data utilized in setting up the DO-CAL model for the White River was based on information obtained during a cooperative 48-hr. field study of the river by the Federal Water Pollution Control Administration and the Indiana State Board of Health personnel in June, 1967. Table 4 gives a summary of the temperature and dissolved oxygen conditions encountered during the 1967 study from Indianapolis downstream to Martinsville.

TABLE 4

Station		D.O. mg/l	Temp. °C.
1. White River at Morris St--Indianapolis (Mile Pt. 231.10) Flow - 312 cfs	Avg.	8.0	24.5
	Min.	6.5	23.0
	Max.	10.6	27.0
2. S.T.P. No. 1 Effluent Harding St. Plant (Mile Pt. 228.58) Flow - 133 cfs	Avg.	2.8	24.0
	Min.	1.9	23.0
	Max.	3.9	27.0
3. White River at I-465 (Mile Pt. 225.13) Flow - 468 cfs	Avg.	1.7	27.0
	Min.	0.4	23.0
	Max.	3.2	31.0
4. S.T.P. No. 2 Effluent Southwest Plant (Mile Pt. 222.40) Flow - 38 cfs	Avg.	4.4	22.3
	Min.	3.4	21.0
	Max.	5.4	27.5
5. White River at Southport Rd. (Mile Pt. 222.09) Flow - 523 cfs	Avg.	1.9	27.2
	Min.	0.3	25.0
	Max.	4.9	30.0
6. White River at Waverly, Ind. (Mile Pt. 211.00) Flow - 555 cfs	Avg.	3.1	25.4
	Min.	0.9	21.0
	Max.	6.1	29.0
7. White River at Henderson Bridge (Mile Pt. 202.57) Flow - 590 cfs	Avg.	4.9	25.2
	Min.	1.5	23.0
	Max	9.7	27.0
8. White River near Centerton (Mile Pt. 199.21) Flow - 637 cfs	Avg.	5.9	25.1
	Min.	2.1	23.0
	Max.	11.4	27.0
9. White River at Martinsville, Ind. (Mile Pt. 191.60) Flow - 650 cfs	Avg.	6.0	27.8
	Min.	3.8	23.0
	Max.	10.1	31.0

1. The mile points indicated are measured from the mouth of the White River.
2. The streamflows and effluent discharges are averages for the two-day period.

TEMPERATURE PREDICTION

Bernard R. Sacks

This report attempts to determine the equilibrium temperature for normal summer meteorological conditions and the equilibrium temperature for a severe hot period. The prediction of river temperatures is based on an analysis of the meteorologic and hydraulic factors affecting the stream's heat balance.

The normal weather conditions for the Cincinnati area, based on 30 years of record (1931-1960), were obtained from the Environmental Science Services Administration (Weather Bureau), U.S. Department of Commerce. Calculations for determining the equilibrium water temperatures were based on the following factors: air temperature, vapor pressure, wind speed, and long and short wave radiation. The equilibrium temperatures for the months June to September (Table 1) are daily averages and are slightly higher than the average air temperature. This is due to the combination of relatively slow winds (5-6 1/2 mph) and high humidities (65-71 per cent). These factors cause the water to absorb heat from the radiation with little heat loss due to evaporation.

The equilibrium temperatures are in the ranges of the data collected by ORSANCO in the years 1963 to 1968 for the Ohio River at Cincinnati (Table 1). These temperature ranges are the daily averages for the month.

The Weather Bureau reported that 1936 was a hot year. Therefore the month of July with an average of 82°F was used for air temperature. If a 5 mph wind is assumed, with 75 per cent humidity, and 90 per cent of the maximum potential sunlight, a figure of 88°F is obtained for the equilibrium temperature, which is slightly higher than the maximum daily ranges for the period June-September, 1963-1968. However, this would be a very extreme condition.

Heat dissipation from a body of water which has been heated above its equilibrium temperature with the meteorological conditions follows Newton's Law of Cooling. This law states that the rate of cooling is proportional to the difference between the temperature of the body of water and the equilibrium temperature for the given meteorological conditions. This is analogous to the exponential die-away curve for radioactive decay.

To demonstrate a theoretical thermal die-away curve for the Markland Pool area, an assumed heat load was placed at mile 460, which is in the upper end of the pool. Figure 1 shows the curve for a flow of 10,000 cfs. This is a classic exponential die-away curve modified for the changing cross-sectional area as one proceeds downstream. Under this assumed flow about 75 per cent of the heat would be dissipated during the approximate 70 miles and 24 days to Markland Dam. At higher flow levels, and a consequent lesser flow time to the dam, a lesser per cent of the heat would be dissipated. In this determination, meteorological conditions are assumed constant and therefore diurnal variations are ignored.

Figure 2 shows the effect of the Beckjord Plant at mile 453. With a heat contribution of 5.8×10^9 BTU per hour, the temperature rise in the Ohio River (river flow 10,000 cfs minimum) would be 2.6°F. Based on a normal June temperature of 72°F for the air, the resulting water temperature immediately downstream of this point would be 78.6°F (equilibrium temperature of 76°F plus 2.6°F). If however, the equilibrium temperature for the hot period is used, the resulting river temperature would be nearly 91°F immediately below the plant. This assumes a complete mixed system. If there is any stratification, there would be the areas where the temperature was higher.

The previous analysis shows that the Ohio River through the Cincinnati area seems to retain any heat added. The amount of heat dissipated is relatively slow, in fact, calculations have shown that it would take over 200 miles of river length under conditions similar to the Cincinnati Pool in order to have dissipated 99 per cent of the heat added.

Table 1. TEMPERATURE COMPARISONS FOR OHIO RIVER AT CINCINNATI

(All Temp. in ^{o}F)

	Air Temp.	Equilibrium Water Temp.	Temp. Range
	1]	2]	3]
June	72	76	61.5 - 80.9
July	75	82	75.1 - 84.4
Aug.	74	81	76.0 - 83.6
Sept.	67	78	67.8 - 81.4

1] Weather Bureau

2] Calculated

3] ORSANCO data collected over period 1963-1968 at Cincinnati

FIGURE 1
TEMPERATURE DROP
THROUGH MARKLAND POOL
OHIO RIVER

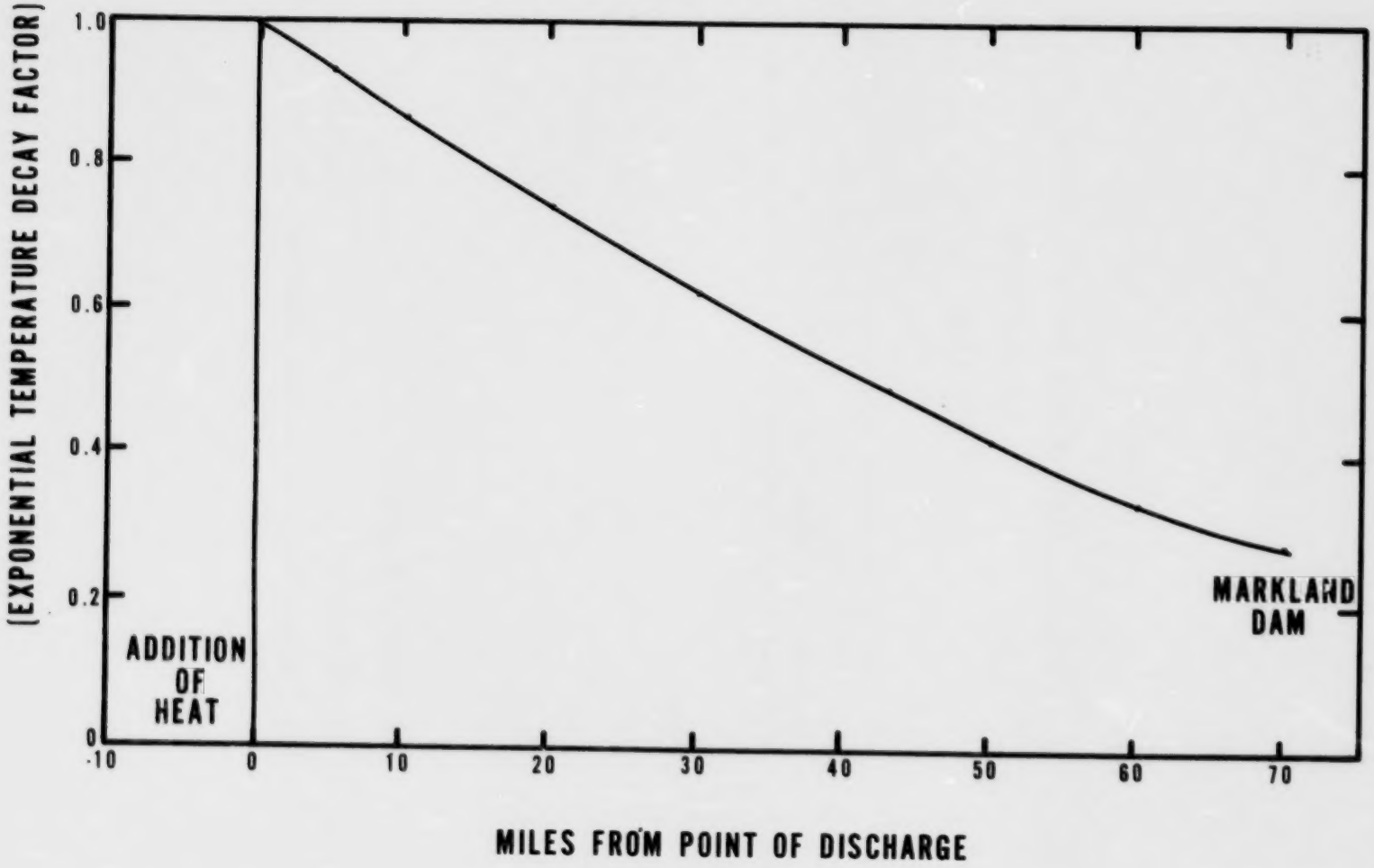
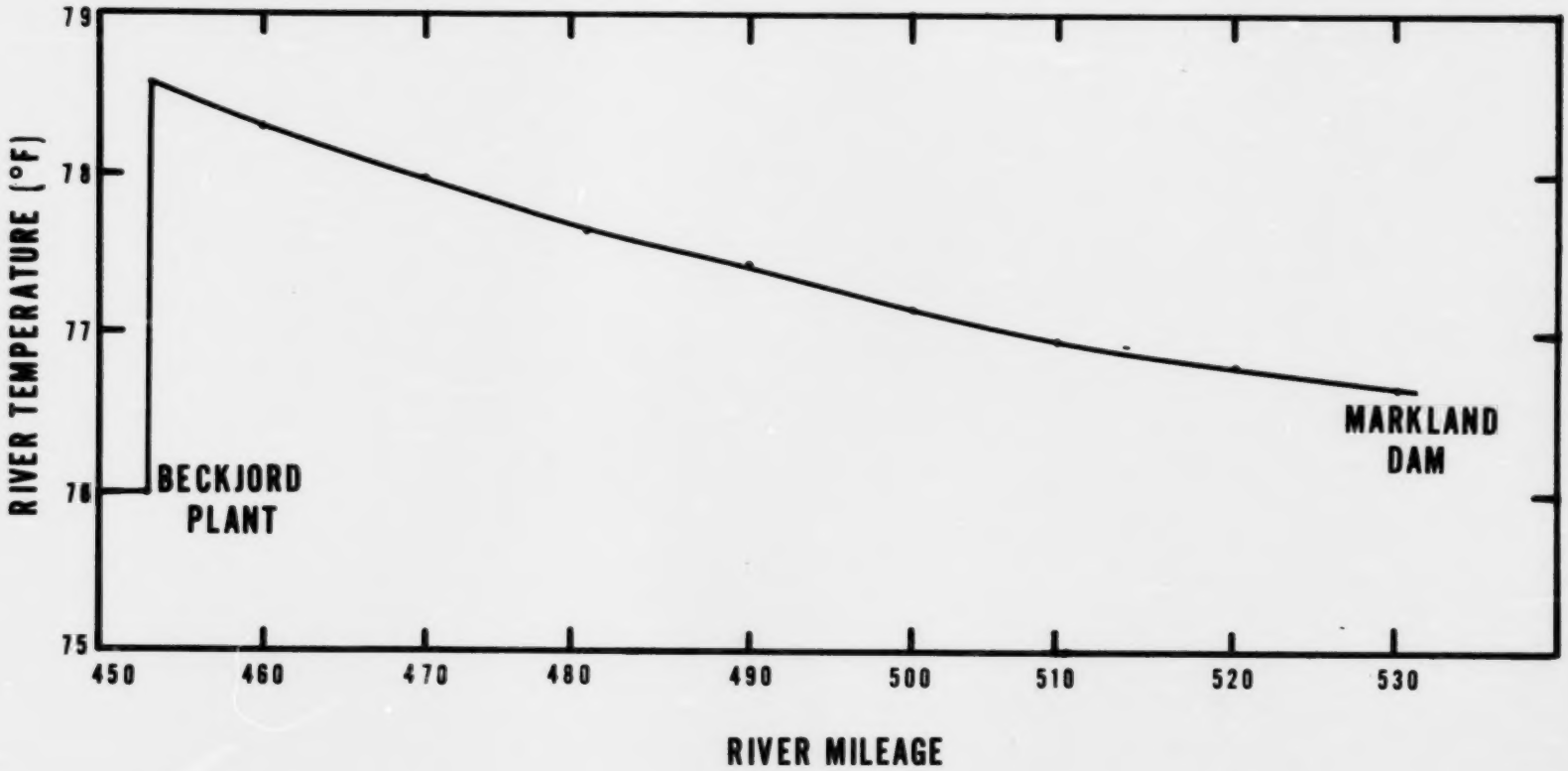


FIGURE 2
TEMPERATURE EFFECTS
OF BECKJORD PLANT FOR MARKLAND POOL
OHIO RIVER



THERMAL POWER-

THE COST OF WASTE HEAT TREATMENT AND CONTROL

Bruce A. Tichenor, Ph.D.

INTRODUCTION

One of the consequences of producing electric energy through the use of the steam cycle is the production of large quantities of waste heat. In accordance with water quality standards for water temperature, this waste heat must be controlled. Several avenues of waste heat disposal are available:

1. Direct discharge to the aquatic enviromnent by once-through cooling.

2. Indirect discharge to the atmosphere through the use of a cooling device such as towers or ponds.

3. Use of the waste heat for beneficial purposes. (Here too, the waste heat must ultimately go into either the water or air.)

4. Combinations of the above.

Considering the fixed or diminishing supply of the Nation's water and the forecasted increase in thermal power generation one is led to conclude that once-through, freshwater cooling is unacceptable for large, new thermal power plants. This conclusion is shared by industrial spokesmen. At the second session of the National Symposium on Thermal Pollution in August, 1968, Shade and Smith (6) stated: "Run of River and Bay/Lake systems for rejecting power plant thermal discharge have a very limited future because of government restrictions."

In a paper presented at the American Power Conference in April, 1969, Hauser (4) concluded that by the late 1970's the fresh water bodies will " . . . reach a point where no further heat can be injected into them without damage to the ecology." Therfore, " . . . the only natural heat sink left will be the oceans." Hauser states that " . . . approximately 31% of the thermal power generation capacity will be able to utilize sea water cooling." Thus, he concludes " . . . that during the end of the 1970's approximately 70% of the new base load generation to be installed in this country will utilize some form of supplementary cooling apparatus."

Most new thermal power plants will use cooling devices. The purpose of this paper is to discuss the economic impact of cooling--how it affects the power industry and the consumer.

COOLING SYSTEMS

Cooling water systems can be divided in to two major categories:

1. Once-through Systems. In a once-through system the cooling water is taken from a water body, passed directly through the condenser where it extracts energy from the condensing steam and discharged back to the receiving water at an elevated temperature. Throughout the nation, the temperature rise in once-through systems varies from 10° to 25°F and averages about 15°F. The amount of thermal energy discharged to the receiving water is a function of plant size, overall efficiency, and load factor.

2. Closed-cycle Systems. Closed-cycle systems use an "off stream" cooling device to reduce the temperature of the condenser discharge. Cooling water is used again and again, thus the terms "recycling" and "recirculation" are often used to describe a closed-cycle system. Evaporative cooling devices are most commonly used. Only relatively small amounts of make-up water are required from an outside source. The amount of make-up water required depends upon evaporative and blowdown losses. Blowdown is a process of removing water from the system to prevent a buildup of dissolved solids in the cooling water. Blowdown rates are a function of receiving water quality and the rate of evaporation. Make-up water requirements are normally about 4% of the total cooling water flow, with evaporation accounting for 1 to 1 1/2% and blowdown for 2 to 3%.

In evaluating the effect of cooling facilities on the cost of a plant and on the cost of producing power, the cooling facilities should not be considered independently from the plant, but rather they must be considered an integral part of the plant in any economic evaluation. Therefore, rather than look at each component of a power plant with respect to its individual effect on the total cost of producing power, a more useful approach is to compare the costs of thermal power generation from plants employing several different types of cooling systems.

Five different cooling systems presently being used have been selected for comparison here (dry cooling devices have not been included because they are generally not economically feasible for large steam power plants):

1. Once-through Fresh Water.
2. Once-through Sea Water.
3. Closed-cycle with Cooling Pond.
4. Closed-cycle with Wet Mechanical Draft Cooling Tower.
5. Closed-cycle with Wet Natural Draft Cooling Tower

COST COMPARISONS AMONG COOLING SYSTEMS

Table 1 presents data from several sources to compare the costs of power produced by plants using the various cooling systems described above. The cost of once-through fresh water cooling is used as a base, and the other four systems are compared to this base. The numbers indicate the difference in total production costs (in mills per kilowatt hour.) The effects of both capital and operating costs are reflected in these figures. The assumptions used regarding plant load factor, interest rates, amortization, etc., are given.

Table 1 indicates the economic influence of cooling systems but does not account for the variability in other factors which should be considered in minimizing power costs. Such factors as transmission distance and bond interest rates may have more effect on power costs than the choice of cooling systems.

CONSUMER COST

The foregoing discussion has delineated the increase in production or bus bar costs (Table 1) for plants using various cooling systems as compared to those using once-through cooling. Who pays for the increased costs? Naturally, the cost increases are borne by the consumer. It is important to note, however, that production cost variation is not the only factor influencing consumer costs. The amount the consumer pays for electric power is substantially higher than the actual production costs--transmission, administration, maintenance, advertising, etc., all add to the consumer costs. In some cases the production cost may be only 20% of the consumer costs (2).

TABLE 1

COST OF COOLING ABOVE THAT REQUIRED FOR

ONCE-THROUGH FRESH WATER SYSTEMS

(mills/K.W.H.)

Cooling System	Hauser(4)	Battelle(1)	Converse(2)	Lof & Ward(5)
Once-through Sea Water	0.0336	0.023	--	--
Cooling Pond	0.0331	0.092	--	--
Wet Mechanical Draft Tower	0.1557	0.150	0.16	0.2 - 0.3
Wet Natural Draft Tower	0.1446	0.138	--	--

The figures shown in Table 1 were derived from analyses which used the following assumptions:

Hauser (4): Based on estimated capital, operating, and maintenance cost for a typical U.S. 1000 MW nuclear plant; 14% annual fixed charge rate and 80% plant load factor.

Battelle (1): Costs are those determined in studies of 16 example locations suitable for siting 1000 MW nuclear plants in the Pacific Northwest. Analyses were performed on 18 cooling systems at the sites as follows:

Fresh Water (Once-through)	- 6
Salt Water (Once-through)	- 6
Cooling Pond	- 1
Mechanical Draft Towers	- 1
Natural Draft Towers	- 4

Public agency financing was assumed (100% bonds . . . 4 1/2% effective interest rate); 80% plant load factor.

Converse (2): Costs are those used by Vermont Yankee Nuclear Power Corporation in evaluating plant and cooling costs for the proposed plan at Vernon, Vermont. Annual fixed charge rate = 8.42%; 85% plant load factor.

Lof and Ward (5): Analyses of costs of cooling under typical conditions in the United States.

The Federal Power Commission has published information on 1966 consumer cost of electric power by all utilities. Data from several Ohio Basin utilities are shown in Table 2.

TABLE 2

1966 CONSUMER COST OF ELECTRIC POWER (3)

(mills/K.W.H.)

Utility	Industrial	Commercial	Residential
Indianapolis Power and Light	11.4	23.5	20.5
Cincinnati Gas and Electric	10.7	20.1	25.4
Louisville Gas and Electric	9.5	25.4	21.3
Monongahela Power Co.	8.7	20.0	23.9
U.S. Average	9.78	21.29	23.40

To demonstrate the impact of thermal pollution control on the consumer, one can compute the per cent increase in consumer costs due to the increase in production cost. If we assume that other charges are not affected by the type of cooling system, the data from Table 1 can be used with the data from Table 2 to make this calculation. Table 3 shows the effect of cooling system type on the electric power cost for the average United States consumer (based on 1966 prices). As In Table 1, once-through fresh water cooling was used as the base. The consumer costs associated with the different cooling systems are compared to this base.

TABLE 3

AVERAGE U.S. CONSUMER COST INCREASE

(in per cent)

Cooling System	Industrial	Commercial	Residential
Once-through Sea Water	0.34	0.16	0.14
Cooling Pond	0.94	0.43	0.39
Wet Mechanical Draft Cooling Tower	3.17	1.41	1.28
Wet Natural Draft Cooling Tower	1.48	0.68	0.62

These data were computed using the maximum figures from Table 1 and assume that the cost increase, in mills/K.W.H. is applied equally to industrial, commerical and residential consumer rates. These figures further assume that the cost of all the power purchased by the consumer will be increased in the same proportion as that produced by a single plant using the specified cooling system. Thus, the effect of merging a single plant into an existing power system is not accounted for. These assumptions tend to make the data in Table 3 conservative (i.e., the values are probably too high).

CONCLUSIONS

The foregoing data and analyses show that the cost of providing thermal pollution control is not a restrictive factor in the production of electricity. Incremental increases in the production cost of electricity from plants with closed-cycle cooling over those with once-through fresh water cooling are not excessive. More importantly, the impact of thermal pollution control on the consumer cost of electricity is minimal.

Experts in the field, such as consulting engineers and system planners agree with these conclusions:

Shade and Smith state that,

> "Cooling by means of closed systems such as cooling towers and captive cooling ponds is not prohibitive either in initial capital costs, but these costs are not so low they can be ignored."

Lof and Ward (5) concur,

> ". . . the additional on-site costs incurred by the power plant (and passed along, in turn, to the power users), due to recirculation cooling are only a small per cent of total cost of electricity generation and distribution."

Finally, Hauser (4) concludes that,

> "The economic penalties associated with alternative cooling systems will not deter the electrical generation growth in this country."

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TEMPERATURE EFFECTS ON FISHES-

IMPLICATION FOR AQUATIC LIFE FROM HEATED DISCHARGES

Donald I. Mount, Ph.D.

The concern over the addition of heated water to our natural waterways is a subject that needs no introduction since it has been in the headlines frequently. One might gain the impression, from reading various accounts in the public news media, that little else is important in the field of water pollution. It might be well to examine the reasons for this intense interest before discussing the research planned or underway at the National Water Quality Laboratory. One can summarize our understanding of the effects of temperature on aquatic life by simply saying that while much work has been done, essentially no conclusions have been drawn except that when the temperature gets too hot aquatic organisms die; when it gets too cold they don't grow.

Because temperature is easily measured and easily controlled, a large volume of research has been published on the effects of temperature on aquatic organisms. Because temperature has a rather obvious regulatory influence on any animal that does not control its body temperature, it is a variable which is inviting to study in experimental work. As a result, many inexperienced investigators have studied the effects of temperature on aquatic organisms and published their results without fully understanding the problems they confront.

Increasingly evident is the fact that much of the controversy among "experts" stems from several conditions which are often not considered when field or laboratory observations are being made. For example, the problem of thermal stratification is infrequently considered when temperature measurements are made, especially in field observations related to distribution and well-being of aquatic organisms. One frequently hears it said that a certain species of fish was living at 105°F or some other very high temperature; however, when the facts are fully known, it becomes obvious that the temperature was taken near the surface where the highest temperatures usually occur, and that the temperature where the fish was observed might have been 10, 20 or more degrees cooler than the measurement reported.

Many investigators forget that a lethal temperature does not necessarily kill instantly, and that several hours or several days may pass before any adverse effect is apparent. Thus, it is not at all surprising to observe fishes in temperatures that have been shown to be lethal. Observation of fishes in heated discharges is often taken to mean that this is the most desirable place or the most optimum situation for that particular species. A moment's thought might reveal that many organisms including man (and perhaps especially man) are at times attracted to situations and environments that are clearly not best for them.

On the other hand, the obvious fact that above-normal temperatures may be quite beneficial to the organisms, and that the addition of heat may be highly desirable rather than totally adverse, is also often ignored.

The effects of climate, particularly during the summer months, are often not considered in evaluating the amount of heat that may be added without adverse effect. A fish species living in the northern part of its range will be able to thrive well under a greater increase in ambient temperature than would the same species living in the southern part of its range where the natural temperatures may frequently approach the upper limit. Indeed, that is the reason, in all probability, this particular area is on the southern boundary of the range of that species.

Perhaps one of the greatest causes for confusion and excitement is the very pronounced tendency to consider "aquatic life" as having a specific temperature requirement throughout the entire United States. This tendency leads to the conclusion that if that one temperature can be determined, all problems can be solved. As water use increases, we must become more and more sophisticated in establishing standards of water quality to protect all uses. Great margins of safety to insure completely safe concentrations are not generally accepted as part of our philosophy. For this reason, standards of water quality usually reflect the very maximum temperature which can be tolerated.

This "brinkmanship" approach makes it necessary to consider each species of fish to be protected and the requirements of each species before an acceptable standard can be developed. It is not uncommon to hear of a discharger who pitifully recounts that a fish kill occurred because the Corps of Engineers changed the flow on the stream. That discharger should know that if he is going to ride the threshold of

maximum contamination of the environment, he will have to alter the discharge rate as soon as the flow changes slightly; he can't blame his plight on the neglect of other parties.

In regard to present research efforts, it appears that few people are concerned about assembling and digesting the existing information regarding thermal effects on aquatic organisms. Even worse, it seems that few people are concerned about identifying what objectives we are trying to achieve. It is doubtful that the National Aeronautics and Space Administration would have achieved the apparent success of putting a man on the moon in ten years if they had started programs to place men on five other planets concurrently with that effort. The potential number of objectives germane to development of thermal requirements for aquatic organisms is enormous; if we are to make any real progress in providing answers to those who must discharge heated water, we will have to select goals and concentrate our efforts. The research program at the National Water Quality Laboratory has at least identified specific objectives. While that program may not provide the answer to final selection of objectives, we are making progress.

With the help of approximately 30 experts, a list of important fish species has been drawn up. We are studying these species in order to provide in-depth information about each species so that meaningful standards can be developed. Likewise, work on fish food organisms is focused on those organisms which provide an important part of the food web of the selected fish species. There is no intent to imply that all organisms will be protected by criteria developed to protect these selected species. There is an intentional implication, however, that conditions suitable for the well-being of these selected species will provide a diversified sport and commercial fishery superior to many of those now in existence.

A critical review of the temperature literature is part of our program; while general reviews have been published we must consolidate the information on a species-by-species basis so that existing knowledge can be used to supplement new information as it is developed.

Consolidation of this information into a usable format is of prime importance. At the present time our knowledge is

restricted essentially to laboratory-derived lethal temperatures, preferred or selected temperatures based on field observations, some small amount of information on temperature gradients that are avcided by a few species, temperatures that appear to attract certain species, and finally, some information regarding temperature requirements of eggs and fry of some of the species more commonly raised in hatcheries. The recommendations contained in the report of the National Technical Advisory Committee to the Secretary of the Interior regarding water quality criteria for aquatic life have been widely quoted. Unfortunately, the recommendations regarding temperature criteria have been misused and may lead to trouble in some places. The five-degree incremental rise proposed in that report has been indiscriminately used without regard to the specific situation or the specific water of concern, and there seems to have been little attempt to base this rise on the temperature regime as recommended.

Users of the report have not recognized that the Committee was obligated to make recommendations applicable from northern Minnesota to the southern tip of Florida, and that specific acceptable temperatures could not be suggested without knowledge of the species to be protected and the type of waters upon which the standards were to be applied.

This problem has been carefully considered in the research program at the National Water Quality Laboratory in Duluth. We have concluded that to remedy this situation a family of curves must be developed to represent annual temperature regimes and to identify desirable species able to thrive under each of these temperature regimes. This family of curves will not be related in any way to an incremental rise, nor will it require previous records of temperature before the additions of heat began. Each curve will show the length of time that the temperatures are near or at the maximum during the summer months, and will indicate the amount of cooling required to initiate reproduction during the winter period. It is probable that the difference between summer and winter maxima will vary with the species and that for some species, no winter chill period will be needed. There is no reason why we should not take advantage of the growth potential that heat additions in the winter months can provide, so long as we are certain that the species of concern can reproduce normally in the spring season and that the proper food organisms will be present at the time they are needed.

Our work has been divided into six separate categories, each with a specific objective. Taken together, they form the general objective of developing a family of curves. The specific objectives are to:

1. Determine which selected species require a chill period during the winter months in order to initiate reproduction.

2. Determine the critical periods in the life cycle of the desirable species and the temperatures required during these critical periods.

3. Determine the temperatures which provide optimum growth for individual species.

4. Establish temperature requirements for food organisms of the species known to be important or essential.

5. Evaluate the rate of change acceptable for various species.

6. Verify laboratory-derived results in a semi-natural situation where all elements of ecosystem must function together to produce the harvestable crop.

Many of these objectives are being studied as part of our in-house research program; others are being studied in extramural research grants and contracts.

Presented below is a brief summary of the in-house research efforts currently underway, or expected to be underway in the near future.

We are conducting a battery of tests to determine the thermal requirements for normal egg maturation, incubation, hatching, fry growth and survival for yellow perch, white suckers, northern pike, and brook trout. Tests completed on these species during the past year are now being repeated to provide duplicate sets of data in an attempt to obtain statistical validity. The general measures of effect being used in these tests are the size and normality of the fry produced under the various temperature conditions. Workers have long suspected that the requirements of the fry are among the most demanding, especially in regard to temperature and oxygen; for this reason, this phase of the work is considered of prime importance.

The tests to date have revealed several important facts; for example, white suckers stay at the surface after hatching. This species might therefore be eliminated if a heated discharge was made at the surface during the spawning season.

Not all of our selected species can be tested at the Duluth laboratory. We expect to utilize contracts to complete work on the other species in order to complete this part of the thermal pollution research program.

A temporary field site has been established in cooperation with the Northern States Power Company at their fossil fuel plant on the St. Croix River. There, we have leased a building situated with one end near the intake and one end near the discharge of the power plant. The condenser water is used as a source of heat in order to maintain 56 six-hundred-gallon tanks at various elevated temperatures. This system provides facilities to determine for each species simultaneously the maximum sustained temperature which will provide the best growth, which species do not need a winter chill period in order to reproduce, and to collect some data on the maximum tolerable temperatures under which acceptable reproduction can occur. The principal objective of this research effort is to determine which of the eight species being studied require a cooler period during the winter months in order to initiate reproduction. The information gathered on the growth and survival under sustained elevated temperatures is also important. Much of the information obtained in this study will be useful in our field evaluation studies.

We are also trying to determine the specific foods required to provide an acceptable diet for fry when they first begin to feed. Experts in the field of fish population dynamics generally agree that for many species, the survival of the year class is related to the first few weeks after the fry begin to feed. We are studying the specific food requirements during that period so that the thermal requirements of those essential food organisms can be established.

Studies to date indicate that the proper food, rather specific in nature, must be available within a span of a few hours after the time the fry are ready to begin feeding. It is also generally conceded that older fishes are able to thrive on a variety of diets, and that there are very few cases where only one or a few food types are essential to the production of desirable fish crops.

Another facet of our work is development of the thermal requirements for important fish food organisms such as the common aquatic insects and the important and abundant benthic and planktonic crustaceans. The studies to date on fish food organisms have been somewhat frustrating because it is very difficult to determine whether or not the particular food organisms being studied are really essential to the production of the fish crop, or whether they are simply one kind of food that can be used by a certain species.

The question arises whether the food of those food organisms will be able to survive under the same temperature regime. For this reason, we have felt it necessary to complete testing in semi-natural situations where thermal effects on the entire food web can be included in the test, and where the final measure of effect can be the pounds per acre of fish produced. This effort also will be made possible in part by the cooperation of Northern States Power Company at a site located upstream from Minneapolis on the Mississippi River and adjacent to a nuclear power plant in the final stages of construction. Final negotiations are now in progress to utilize land acreage near the plant to build experimental ponds where temperatures can be maintained at various elevated temperatures throughout the year, and in ponds large enough that the effect can be measured in pounds of fish produced.

Our preliminary design calls for the capacity to maintain eight acres of water twenty degrees above the normal ambient temperatures, even when air temperatures are in the sub-zero range. Many design and engineering problems remain to be solved before this testing will be possible, and we hope to complete a contract soon to begin design studies for this experimental facility.

From this last described effort we hope to put together the pieces of the thermal research program, into an integrated whole. From this integrated effort we hope to establish the family of curves mentioned above--curves that will enable regulatory agencies to know what species of aquatic life will be protected under various annual temperature regimes. There are a number of related questions which could be effectively studied at this facility. Since we will be able to maintain stratification in these ponds, it might be possible to examine the effects of thermal additions to the epilimnion or the hypolimnion or through complete mixing. We have only recently begun to examine the many possibilities that exist for meaningful research at this installation, and at this time the final plans and specific objectives are not clearly established.

In conjunction with this semi-natural study, we hope to cooperate with the Tennessee Valley Authority in a thermal research program in Tennessee where stream situations will be tested in a manner somewhat similar to those described for the ponds in Minnesota.

There are many other segments of the program being supported through extra-mural contracts and grants. These generally fall into one of the categories mentioned in the above list of objectives. The FWPCA has a center in Corvallis, Oregon, for the national thermal pollution research program. Under the direction Mr. Frank Rainwater, engineering problems relating to heat mixing and distribution are being studied and predictions made of heated effluent patterns in natural waterways. Engineering aspects of design for distribution and control of thermal additions are the main objectives of this work. Work is also being conducted on the beneficial uses of waste heat. The program at the National Water Quality Laboratory in Duluth is oriented towards resolving problems concerning the effects of heated discharges on the aquatic environment.

It is imperative that those concerned with the problems of thermal pollution work together towards selected objectives. It will be a long time, if ever, before all information that is really needed to establish precise thermal standards is available. This being the case, it is essential that we narrow our approaches, so that in-depth information can be obtained and practical answers provided for the pressing problems of increasing water uses that will undoubtedly develop on most of our water courses.

Finally, a word of caution--as the margin for safety is reduced, the complexity of the standards must increase and closer attention must be given to changes in stream flow and water quality. At some point, it becomes more feasible to provide treatment than to attempt to balance input with stream conditions so critically that the probability of causing a catastrophe becomes unacceptably large.

FISHERY COMPCSITION STUDIES-

OHIO RIVER BASIN

1967-68

H. Ronald Preston

INTRODUCTION AND OBJECTIVES

In 1967 the Wheeling Office, Ohio Basin Region, FWPCA, initiated fish population and composition studies in the Allegheny, Monongahela, Kanawha, and upper Ohio Rivers. In 1968, through the development of an interagency committee, the program was expanded to include studies of the lower Ohio River by the Evansville, Indiana Office. The interagency committee is composed of personnel representing FWPCA, ORSANCO, Bureau of Sport Fisheries and Wildlife, U. S. Army Corps of Engineers, Bureau of Commercial Fisheries, Pennsylvania Fish Commission, West Virginia Division of Wildlife, Kentucky Division of Fisheries, and the Ohio Division of Wildlife. The studies will extend through 1972.

The objectives of the studies are to:

1. Measure the effect of pollution on a beneficial, legitimate use of interstate waters.

2. Provide a revolving accumulation of baseline data for evaluation of water quality changes and pollution control as related to the fishery resource.

3. Evaluate the palatability of sport and commercial food fishes.

4. Compare the results of the 1957-59 ORSANCO-University of Louisville study with present data and evaluate the discernable differences in relation to water quality changes.

METHODS

As in the earlier ORSANCO-University of Louisville study, lock chambers in the canalized portions of the mentioned rivers were chosen for the fish sampling. Rotenone (5% emulsified)

was applied to the closed chambers at the rate of 1 mg/l. The emulsified rotenone was pumped to a depth of 20 feet and also applied to the surface.

All fish collected are identified, measured and weighed. Sample collections were preserved from each of the locations. Dr. Edwin Cooper of Pennsylvania State University, Dr. William Clay of University of Louisville and fisheries biologists from other Federal and State agencies provided assistance in identifying most of the collections.

RESULTS

Table 1 lists the lock chambers and pertinent information for the lock chambers sampled in 1968. Table 2 summarizes results of this sampling and of the initial 1967 study. Table 3 shows distribution of the fishes collected in the Ohio River during this study. Exhibit A includes the results of the individual lock chamber studies conducted in 1968.

OHIO RIVER MAIN STEM

In 1968, a total of 6,936 pounds of fish was collected from 16 lock chambers in the Ohio River from mile point 13.3 to mile point 876.8. Percentage composition (by weight) of the predominant fishes collected was as follows: gizzard shad, 41%; carp, 30%; channel catfish, 10%; freshwater drum, 5%; bullheads, 5%; sunfish, 2%; various other species accounted for the remainder.

Cursory examination of the first complete year of this study indicates a close similarity to the results of the 1957-59 study.

Table 4 compares selected species and families with their respective weights for the Ohio River sampling locations. For comparison purposes on a common measuring unit, the Table lists estimated pounds per acre values.

Examination of Table 4 indicates the following trends:

1. Carp and bullhead populations are predominant in the fishery composition in the upper portions of the Ohio River.

2. Gizzard shad become predominant in the middle and lower portions of the river.

3. Channel catfish populations appear to be less abundant in the upper Ohio than in the middle and lower portions.

4. Sunfish (including black bass and crappies) are more abundant in the lower Ohio than in the upper portion.

5. The freshwater drum makes up a much greater proportion of the fish population in the lower Ohio than in the upper portion.

6. Emerald shiners collections were more abundant in the upper-middle portion of the Ohio River (mile point 129 to mile point 279).

7. Walleye specimens were very few and were scattered throughout the river.

8. Significant sauger collections were concentrated in the Kentucky portion of the Ohio River above Cincinnati, Ohio. Sauger composed over 50% (by weight) of the sport fishes collected in 1968 at Greenup and Meldahl lock chambers. A significant number of sauger were collected in the embayment at Lock and Dam No. 50 (mile point 876.8). Worthy of note is the fact that this collection consisted mostly of young-of-the-year specimens, indicating successful reproduction in the Ohio River. Table 5 gives a complete breakdown of the number, weight and size of sauger collected in 1968.

Table 6 lists the distribution of sport fishes (by number and weight) collected in the Ohio River lock chambers during 1968. The crappies (white and black) composed 36% by weight of the total sport fishes. Of the larger, more desirable sport fishes, i.e., black basses, walleye and sauger, the sauger was the second most abundant of the sport fishes. As mentioned, the greatest number of sauger was collected at the Greenup and Meldahl chambers.

The sport fishes, as listed in Table 6, make up less than 3% (by weight) of the total fish collected in the Ohio River during 1968. Channel catfish, which may be considered a sport fish, accounted for 10% of the total weight collected.

TRIBUTARIES

Fish population studies were conducted on the Kanawha, Allegheny and Monongahela Rivers in 1967 and 1968. Table 7 is a comparison of selected species and families of fishes collected in these tributaries. The results of these samples

appear to be erratic; however, the following comments are offered.

Kanawha River

The London Lock chamber yielded very different results for each year of the sampling and, at the present time, no explanation can be offered for these results.

The Winfield sampling location, downstream of a heavily polluted section of the Kanawha, yielded a surprising number of fish for each year. Carp were the predominant species for both collections.

Monongahela River

The Maxwell Lock Chamber is located in the portion of the Monongahela River greatly affected by mine drainage pollution. A pH reading of 3.9 was recorded during the 1968 sampling.

The sampling at Lock and Dam No. 2 yielded a much greater number of fishes in 1968 than in 1967. Carp and bullheads predominated the composition.

Allegheny River

The Allegheny River samples collected in 1967 and 1968 did not show great differences from year to year. Species composition is well distributed at Lock and Dam No. 8 and without a single species predominating. The samples collected at Lock and Dam No. 3 were predominated by carp and bullheads.

SUMMARY

Since the studies are programmed to be conducted over a five-year span, it is premature to cite definitive conclusions. In general, however, the overall picture of the Ohio River fishery resources appears to be one predominated by rough or undesirable fishes for sport and commercial uses. The river supports fish life and, as indicated by these initial studies, apparently in abundance. There are also indications that certain sections approach a more desirable or "balanced" fish population. Certainly additional study is needed to document these conditions.

The Ohio River fish population is a product of environmental factors. The findings of this study will provide further information for identifying those factors and will produce recommendations for environmental management to achieve a more desirable and beneficial natural resource.

Table 1
Location and Description of Sampled Lock Chambers, Ohio River Basin, 1968

River	Location	Mile Point	Date	Method	Depth (ft.)	Surface Area (Acres)*	Temperature °C	Dissolved Oxygen (mg/l)	Secchi Transparency (ft.)
Kanawha	London L & D, W. Va.	82.8	8-28-68	1 mg/l Rotenone	18	.5	27.0	7.6	2.5
Kanawha	Winfield L & D, W. Va.	31.1	8-29-68	1 mg/l Rotenone	14	.5	26.5	1.5	6.0
Monongahela	Maxwell L & D, Pa.	61.2	9-10-68	1 mg/l Rotenone	20	1.4	23.0	8.6	7.0
Monongahela	L & D No. 2, Pa.	11.2	9-11-68	1 mg/l Rotenone	21	.5	25.5	6.3	3.5
Allegheny	L & D No. 8, Pa.	52.6	9-17-68	1 mg/l Rotenone	15	.5	21.0	8.4	2.0
Allegheny	L & D No. 3, Pa.	14.5	9-18-68	1 mg/l Rotenone	15	.5	23.0	8.5	5.5
Ohio	Dashields L & D, Pa.	13.3	9-12-68	1 mg/l Rotenone	22	.5	23.0	6.5	---
Ohio	Montgomery L & D, Pa.	31.7	9-19-68	1 mg/l Rotenone	19	.5	23.5	9.3	3.8
Ohio	New Cumberland L & D, W. Va.	54.4	9-24-68	1 mg/l Rotenone	20	1.5	---	---	---
Ohio	Pike Island L & D, W. Va.	84.3	9-25-68	1 mg/l Rotenone	22	1.5	26.0	7.4	3.0
Ohio	L & D No. 15, W. Va.	129.1	9-26-68	1 mg/l Rotenone	13	1.5	25.5	8.3	2.6
Ohio	Belleville L & D, W. Va.	204.0	10-1-68	1 mg/l Rotenone	28	1.5	23.5	---	3.6
Ohio	L & D No. 23, W. Va.	231.0	10-2-68	1 mg/l Rotenone	12	1.5	23.5	8.5	3.0

Table 1 (continued)

River	Location	Mile Point	Date	Method	Depth (ft.)	Surface Area (Acres)*	Temperature °C	Dissolved Oxygen (mg/l)	Secchi Transparency (ft.)
Ohio	Gallipolis L & D, W. Va.	279.2	10-3-68	1 mg/l Rotenone	18	.9	23.0	5.0	2.0
Ohio	Greenup L & D, Ky.	341.0	10-8-68	1 mg/l Rotenone	26	1.5	21.5	---	2.5
Ohio	Meldahl L & D, Ky.	436.4	10-9-68	1 mg/l Rotenone	34	1.5	22.0	---	2.5
Ohio	Markland L & D, Ky.	531.5	9-10-68	1 mg/l Rotenone	23	1.5	24.0	5.0	---
Ohio	McAlpine L & D, Ky.	607.0	9-11-68	1 mg/l Rotenone	12	.5	24.0	9.5	---
Ohio	L & D No. 43, Ky.	633.2	9-12-68	1 mg/l Rotenone	12	1.5	25.0	9.0	2.0
Ohio	Cannelton L & D, Ky.	720.7	9-17-68	1 mg/l Rotenone	13	1.5	23.0	6.0	---
Ohio	L & D No. 47, Ky.	777.7	9-18-68	1 mg/l Rotenone	12	1.5	23.0	9.0	---
Ohio	L & D No. 50, Ky. (embayment)	876.8	8-21-68	1 mg/l Rotenone	12	1.7	29.0	6.5	1.0

*Rounded to nearest tenth of acre

Table 2

Results of Lock Chamber Sampling

1967 & 1968

Ohio River Basin

Location	Mile Point	Surface Acres	No. of Species 1967	No. of Species 1968	Total Pounds 1967	Total Pounds 1968	Estimated Pounds/Acre 1967	Estimated Pounds/Acre 1968
Kanawha River								
London L & D	82.8	.46	18	9	102.83	24.85	224	54
Winfield L & D	31.1	.46	14	10	232.72	100.24	506	218
Allegheny River								
L & D No. 8	52.6	.46	18	23	18.72	68.90	41	150
L & D No. 3	14.4	.46	12	15	21.47	20.46	47	44
Monongahela River								
Maxwell L & D	61.2	1.35	0	1	0.00	0.04	0	---
L & D No. 2	11.2	.46	4	9	2.58	27.99	6	61
Ohio River								
Dashields L & D	13.3	.46	13	16	201.82	253.34	439	551
Montgomery L & D	31.7	.46		19		116.86		254
New Cumberland L & D	54.4	1.51		20		359.71		238
Pike Island L & D	84.2	1.51	18	26	230.68	396.60	153	263
L & D No. 15	129.1	1.51		20		117.69		78
L & D No. 17	167.5	1.51	21		332.04		220	

Table 2 (continued)

Location	Mile Point	Surface Acres	No. of Species 1967	No. of Species 1968	Total Pounds 1967	Total Pounds 1968	Estimated Pounds/Acre 1967	Estimated Pounds/Acre 1968
Belleville L & D	204.0	1.51		22		242.63		161
L & D No. 23	231.4	1.51	14	18	603.98	158.78	400	105
Gallipolis L & D	279.2	.90	25	23	235.97	252.72	262	281
Greenup L & D	341.0	1.51	25	23	428.14	251.50	284	167
Meldahl L & D	436.2	1.51	22	27	684.77	562.43	453	372
Markland L & D	531.5	1.51		22		1057.29		700
McAlpine L & D	607.0	.46		16		177.81		387
L & D No. 43	633.2	1.51		13		73.73		49
Cannelton L & D	720.7	1.51		32		239.49		159
L & D No. 47	777.7	1.51		21		200.59		133
L & D No. 50 (embayment)	876.8	1.70		33		2473.36		1455

Table 3

DISTRIBUTION OF FISHES COLLECTED IN THE OHIO RIVER

Lock Chamber Sampling, September-October, 1967 and September-October, 1968

Species	Mile Point 13	32	54	84	129	168	204	231	279	341	436	532	607	633	721	778	877
Longnose gar Lepisosteus osseus (Linnaeus)							X		X		X	X	X		X		
Shortnose gar L. platostomus Rafinesque																	X
Bowfin Amia calva Linnaeus															X		
Skipjack herring Alosa chrysochloris (Rafinesque)					X	X	X	X	X	X	X	X	X	X	X	X	X
Gizzard shad Dorosoma cepedianum (LeSueur)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Threadfin shad D. (Signalosa) petenense (Gunther)												X			X		
Goldeye Hiodon alosoides (Rafinesque)										X	X				X	X	
Mooneye H. tergisus LeSueur										X					X		
Northern pike Esox lucius Linnaeus										X							
Goldfish Carassius auratus (Linnaeus)				X								X					
Carp Cyprinus carpio Linnaeus	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Silver chub Hybopsis storeriana (Kirtland)				X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 3 (continued)

Species	Mile Point 13	32	54	84	129	168	204	231	279	341	436	532	607	633	732	776	877
Golden shiner Notemigonus crysoleucas (Mitchill)				X											X		
Emerald shiner Notropis atherinoides Rafinesque	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
River shiner N. blennius (Girard)	X										X				X		
Ghost shiner N. buchanani Meek							X	X	X	X	X						
Common shiner N. cornutus (Mitchill)										X							
Rosyface shiner N. rubellis (Agassiz)				X		X										X	
Spotfin shiner N. spilopterus (Cope)		X	X	X	X			X									
Sand shiner N. stramineus (Cope)	X	X	X	X			X	X		X							
Mimic shiner N. volucellus (Cope)		X		X	X	X		X	X	X	X					X	
Steelcolor shiner N. whipplei (Girard)				X													
Suckermouth minnow Phenacobius mirabilis (Girard)						X		X									
Bluntnose minnow Pimephales notatus (Rafinesque)	X	X	X	X	X		X	X	X	X							
Creek chub Semotilus atromaculatus (Mitchill)				X													

Table 3 (continued)

Reproduced from best available copy.

Species	Mile Point 13	32	54	81	129	168	224	231	279	341	436	532	607	633	721	778	877
River carpsucker Carpiodes carpio (Rafinesque)							X				X	X			X	X	X
Quillback C. cyprinus (LeSueur)					X	X			X	X	X				X	X	X
Highfin carpsucker C. velifer (Rafinesque)													X				X
White sucker Catostomus commersoni (Lacepede)	X		X														
Smallmouth buffalo Ictiobus bubalus (Rafinesque)						X		X	X	X	X	X	X		X	X	X
Bigmouth buffalo I. cyprinellus (Valenciennes)															X		X
Black buffalo I. niger (Rafinesque)						X	X		X		X					X	
Spotted sucker Minytrema melanops (Rafinesque)												X			X		X
River redhorse Moxostoma carinatum (Cope)														X			
Golden redhorse M. erythrurum (Rafinesque)	X									X	X						X
Blue catfish Ictalurus furcatus LeSueur												X			X		
Channel catfish I. punctatus (Rafinesque)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
White catfish I. catus (Linnaeus)			X														

Table 3 (continued)

Species	Mile Point 13	32	54	84	129	168	204	231	279	341	436	532	607	633	721	778	877
Black bullhead *Ictalurus melas* (Rafinesque)		X				X				X		X			X		X
Yellow bullhead *I. natalis* (LeSueur)	X	X	X	X		X	X			X		X					X
Brown bullhead *I. nebulosus* (LeSueur)	X	X	X	X	X	X	X	X	X	X	X						
Flathead catfish *Pylodictis olivaris* (Rafinesque)								X	X	X	X	X	X	X	X	X	X
American eel *Anquilla rostrata* (LeSueur)				X			X		X		X	X					
Banded killifish *Fundulus diaphanus* (LeSueur)	X		X														
Pirate perch *Aphredoderus sayanus* (Gilliams)																	X
White bass *Roccus chrysops* (Rafinesque)								X	X	X	X					X	X
Yellow bass *R. saxatilis* (Walbaum)																X	X
Rock bass *Ambloplites rupestris* (Rafinesque)		X		X													X
Smallmouth bass *Micropterus dolomieui* (Lacepede)						X			X								
Spotted bass *M. punctulatus* (Rafinesque)				X	X	X	X		X	X	X		X		X	X	X
Largemouth bass *M. salmoides* (Lacepede)	X	X	X	X	X			X	X	X	X				X		X

Table 3 (continued)

Species	Mile Point 13	32	54	84	129	168	204	231	279	341	436	532	607	633	721	778	877
Warmouth Chaenobryttus gulosus (Cuvier)			X												X		X
Green sunfish Lepomis cyanellus Rafinesque	X	X	X	X	X				X	X	X						X
Pumpkinseed L. gibbosus (Linnaeus)	X	X	X	X	X				X								
Orangespotted sunfish L. humilis (Girard)				X			X			X							X
Bluegill L. macrochirus Rafinesque	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Longear sunfish L. megalotis (Rafinesque)				X						X	X			X	X	X	X
Redear sunfish L. microlophus (Gunther)							X		X	X					X		X
White crappie Pomoxis annularis Rafinesque			X	X	X	X	X	X	X	X	X	X	X		X	X	X
Black crappie P. nigromaculatus LeSueur	X	X	X	X	X			X	X	X	X	X	X		X		X
Yellow perch Perca flavescens (Mitchill)						X											
Log perch Percina caprodes (Rafinesque)	X										X						
Sauger Stizostedion canadense (Smith)				X				X	X	X	X			X	X		X
Walleye S. vitreum (Mitchill)	X	X		X					X	X		X	X				

Table 3 (continued)

Species	Mile Point 13	32	54	84	129	168	204	231	279	341	436	532	607	633	721	778	877
Freshwater drum *Aplodinotus grunniens* Rafinesque			X		X	X	X	X	X	X	X	X	X	X	X	X	X
Brook silverside *Labidesthes sicculus* (Cope)					X												

Table 4

Comparison of Selected Species and Families
from Ohio River Lock Chamber Samples, 1967 and 1968;
Figures Given are Estimated Pounds Per Acre

	Total Weight	Carp	Bullheads	Gizzard Shad	Channel Catfish	Centrarchids	Walleye-Sauger	Drum	Emerald Shiner
Dashields L & D									
1967	439	361.7	57.4	13.4	2.0	1.1	0.0	0.0	X
1968	551	413.0	99.9	20.4	3.5	6.3	3.1	0.0	3.0
Montgomery L & D									
1968	254	171.3	28.7	28.9	10.4	11.8	1.3	0.0	X
New Cumberland L & D									
1968	238	175.4	35.0	6.1	13.3	3.7	0.0	1.9	2.2
Pike Island L & D									
1967	153	65.1	13.1	49.1	7.2	3.8	0.0	0.0	13.2
1968	263	184.3	38.7	13.2	13.2	8.6	2.6	0.0	X
L & D No. 15									
1968	78	7.5	1.1	6.1	35.8	8.2	0.0	X	15.3
L & D No. 17									
1967	220	12.7	2.5	69.2	51.2	1.8	0.0	X	66.2
Belleville L & D									
1968	161	13.4	103.8	6.7	27.7	0.4	0.0	1.5	1.6
L & D No. 23									
1967	400	7.1	0.0	350.4	32.2	2.1	0.0	3.0	2.0
1968	105	9.5	0.5	53.7	28.2	3.8	1.3	1.0	0.9
Gallipolis L & D									
1967	262	34.2	0.9	115.7	60.1	4.4	7.6	12.1	3.3
1968	281	162.5	1.0	20.2	56.7	3.2	1.5	10.8	3.0

Table 4 (continued)

	Total Weight	Carp	Bullheads	Gizzard Shad	Channel Catfish	Centrarchids	Walleye-Sauger	Drum	Emerald Shiner
Greenup L & D									
1967	284	89.1	0.4	37.0	120.9	13.2	4.7	10.0	X
1968	167	50.0	1.2	30.8	49.8	6.4	8.7	10.3	X
Meldahl L & D									
1967	453	55.2	0.0	198.0	100.1	19.6	2.7	9.3	X
1968	372	189.5	0.6	50.9	55.6	5.4	7.2	37.6	X
Markland L & D									
1968	700	298.6	X	276.1	79.5	1.8	0.3	15.1	X
McAlpine L & D									
1968	387	69.1	0.0	174.6	72.2	4.6	0.7	41.1	0.7
L & D No. 43									
1968	49	0.4	0.0	4.0	15.4	0.2	1.2	12.1	0.0
Carnelton L & D									
1968	159	60.6	X	5.7	13.4	25.1	0.9	22.7	X
L & D No. 47									
1968	133	2.0	0.0	3.5	21.1	X	0.0	91.2	2.0
L & D No. 50 (embayment)									
1968	1455	64.9	1.1	1147.5	43.1	27.5	2.2	16.4	X

X = Trace

Table 5

OHIO RIVER

Sauger Data

Lock Chamber Sampling

September-October 1968

Pike Island Lock & Dam, M. P. 84.3

Size Class	15"
Number	1
Weight	1.88
Total Number	1
Total Weight	1.88

Lock & Dam No. 23, M. P. 231.4

Size Class	12"	15"
Number	1	1
Weight	.67	1.26
Total Number	2	
Total Weight	1.48	

Gallipolis Lock & Dam, M. P. 279.2

Size Class	11"	12"	13"
Number	1	1	1
Weight	.34	.47	.51
Total Number	3		
Total Weight	1.32		

Greenup Lock & Dam, M. P. 341.0

Size Class	9"	10"	11"	12"	13"	15"	16"
Number	9	11	9	1	1	1	1
Weight	2.29	3.42	3.83	.62	.62	1.04	1.32
Total Number	33						
Total Weight	13.14						

Meldahl Lock & Dam, M. P. 436.4

Size Class	8"	9"	10"	11"	12"	13"	15"
Number	1	2	9	7	4	2	2
Weight	.10	.38	2.44	2.64	1.96	1.30	2.04
Total Number	27						
Total Weight	10.86						

Table 5 (continued)

Lock & Dam No. 43, M. P. 633.2

Size Class	11"	12"	13"
Number	2	1	1
Weight	.75	.50	.60
Total Number	4		
Total Weight	1.85		

Cannelton Lock & Dam, M. P. 720.7

Size Class	16"
Number	1
Weight	1.40
Total Number	1
Total Weight	1.40

Lock & Dam No. 50 (embayment), M. P. 876.8

Size Class	3"	4"	5"	6"	7"	10"	17"
Number	30	12	18	5	1	1	1
Weight	.60	.30	.70	.35	.05	.30	1.50
Total Number	68						
Total Weight	3.80						

	Number	Weight
GRAND TOTAL	139	35.73

Table 6

Distribution of Game Fishes Collected in the Ohio River, Lock Chamber Sampling, 1968

(Represents a Total Sampled Area of 29.59 Surface Acres)

	Largemouth Bass		Spotted Bass		Bluegill		Other Sunfishes		White & Black Crappie		White Bass		Yellow Bass		Northern Pike		Walleye		Sauger	
	No.	Weight	No.	Weight	No.	Weight	No.	Weight	No.	Weight	No.	Weight	No.	Weight	No.	Weight	No.	Weight	No.	Weight
Dashields L & D	3	.50			13	.11	28	.58	38	1.69							2	1.43		
Montgomery L & D	2	.90			25	.28	50	1.21	46	3.03							1	.60		
New Cumberland L & D	8	1.61			18	.17	8	.14	54	3.71										
Pike Island L & D	11	7.32	4	1.52	31	1.23	26	1.38	18	1.53							1	2.03	1	1.88
L & D No. 15	1	.04	58	10.70	1	.05	33	.39	4	.89										
Belleville L & D			1	.44	11	.10	4	.02	4	.08										
L & D No. 23	9	5.19							1	.29	1	.28							2	1.93
Gallipolis L & D	1	.90	1	.42	4	.36	2	.10	2	1.00	1	.14							3	1.32
Greenup L & D			2	.83	11	1.20	2	.05	50	7.57					1	.77			33	13.14
Meldahl L & D			2	.84	32	2.22	1	.01	58	4.27	2	.71							27	10.86
Markland L & D					24	2.50					2	.21					2	.50		
McAlpine L & D			2	.20	18	.10					9	1.82					1	.33		
L & D No. 43					1	.09	1	.15											4	1.85
Cannelton L & D	4	4.10	7	2.35	116	10.20	14	1.82	65	19.40									1	1.40
L & D No. 47			1	.01	1	.10	2	.30	1	.15	1	.20	1	.20						
L & D No. 50 (embayment)	7	13.00	3	.20	16	2.81	82	5.40	614	25.32	1	.40	3	.41					68	3.80
Total	46	33.56	81	17.51	322	21.52	253	11.55	966	70.96	6	1.73	4	.61	1	.77	7	4.89	139	35.73
% of Total Game Fish Weight		17		9		11		6		36		>1		>1		>1		2		18

Table 7
OHIO RIVER TRIBUTARIES

Comparison of lock chamber samples by selected species or families of fishes; figures given are estimated pounds per acre.

River & Location	Total Weight	Carp	Bullheads	Gizzard Shad	Channel Catfish	Centrarchids	Walleye & Sauger	Muskellunge
Kanawha River								
London L & D								
1967	224	12.4	0.2	27.6	43.1	2.6	0.0	
1968	54	9.6	0.0	0.0	0.0	13.2	0.0	
Winfield L & D								
1967	506	172.8	8.3	292.0	27.8	7.2	0.0	
1968	218	183.5	4.3	0.9	28.0	0.2	0.0	
Monongahela River								
Maxwell L & D								
1967	No Fish Collected							
1968	One Sunfish Collected							
L & D No. 2								
1967	6	0.0	4.2	0.0	0.0	1.4	0.0	
1968	61	28.6	26.7	3.0	0.0	1.3	0.0	
Allegheny River								
L & D No. 8								
1967	41	11.6	0.0	0.0	5.0	2.3	6.1	
1968	150	1.7	0.0	0.0	17.0	2.9	1.7	10.9
L & D No. 3								
1967	47	10.2	25.8	0.0	1.7	6.3	2.2	
1968	44	10.0	29.7	0.0	0.3	2.8	0.0	

APPENDIX

TO

SECTION G

FISHERY COMPOSITION STUDIES-

OHIO RIVER BASIN

KANAWHA RIVER

London Lock & Dam, M. P. 82.8

August 28, 1968

Species	Number	Weight (lbs.)
Carp	7	4.41
Emerald shiner	90	0.34
Flathead catfish	94	13.98
White bass	7	0.24
Longear sunfish	1	0.07
Spotted bass	5	5.39
Smallmouth bass	1	0.38
White crappie	1	0.23
Freshwater drum	13	2.81
TOTAL - 9 species	219	24.85

Winfield Lock & Dam, M. P. 31.1

August 29, 1968

Species	Number	Weight (lbs.)
Gizzard shad	12	0.42
Carp	56	84.43
Emerald shiner	1	0.01
Ghost shiner	1	0.01
Sand shiner	1	0.01
Mimic shiner	1	0.01
Black bullhead	13	2.00
Channel catfish	1961	12.87
Bluegill	2	0.08
Freshwater drum	7	0.44
TOTAL - 10 species	2055	100.28

MONONGAHELA RIVER

Maxwell Lock & Dam, M. P. 61.2

September 10, 1968

Species	Number	Weight (lbs.)
Bluegill	1	0.04
TOTAL - 1 species	1	0.04

Lock & Dam No. 2, M. P. 11.2

September 11, 1968

Species	Number	Weight (lbs.)
Gizzard shad	6	1.36
Carp	45	13.16
Emerald shiner	69	0.60
Fathead minnow	1	0.01
Brown bullhead	69	12.27
Bluegill	3	0.03
Green sunfish	13	0.42
Largemouth bass	1	0.14
TOTAL - 8 species	207	27.99

OHIO RIVER

Dashields Lock & Dam, M. P. 13.3

September 12, 1968

Species	Number	Weight (lbs.)
Gizzard shad	75	9.36
Carp	450	189.96
Emerald shiner	307	1.36
Sand shiner	131	0.52
River shiner	14	0.06
Bluntnose minnow	31	0.19
White sucker	1	0.01
Band killifish	1	0.01
Yellow bullhead	18	0.81
Brown bullhead	494	45.14
Channel catfish	50	1.62
Pumpkinseed	28	0.58
Bluegill	13	0.11
Largemouth bass	3	0.50
Black crappie	38	1.69
Walleye	2	1.43
TOTAL - 16 species	1656	253.34

ALLEGHENY RIVER

Lock & Dam No. 3, M. P. 14.5

September 18, 1968

Species	Number	Weight (lbs.)
Ohio lamprey	1	0.01
Carp	7	4.60
Emerald shiner	482	1.20
Sand shiner	1	0.01
Bluntnose minnow	1	0.01
Brown bullhead	38	13.13
Yellow bullhead	11	0.06
Channel catfish	14	0.12
Green sunfish	1	0.01
Pumpkinseed	3	0.03
Bluegill	2	0.02
Rock bass	6	0.06
Largemouth bass	2	0.01
Black crappie	2	1.16
Logperch	5	0.05
TOTAL - 15 species	576	20.46

OHIO RIVER

Montgomery Lock & Dam, M. P. 31.7

September 19, 1968

Species	Number	Weight (lbs.)
Gizzard shad	79	13.27
Carp	146	78.79
Emerald shiner	7	0.01
Spotfin shiner	1	0.01
Sand shiner	4	0.01
Mimic shiner	19	0.01
Bluntnose minnow	6	0.01
Black bullhead	3	0.09
Yellow bullhead	117	1.87
Brown bullhead	85	11.24
Channel catfish	150	4.78
Golden redhorse	1	0.80
Pumpkinseed	26	0.76
Bluegill	25	0.28
Green sunfish	21	0.41
Rock bass	3	0.04
Largemouth bass	2	0.90
Black crappie	46	3.03
Walleye	1	0.60
TOTAL - 19 species	742	116.86

ALLEGHENY RIVER

Lock & Dam No. 8, M. P. 52.6

September 17, 1968

Species	Number	Weight (lbs.)
Muskellunge	1	5.00
Carp	18	0.79
Emerald shiner	15,400	31.08
Mimic shiner	6,380	12.88
Bluntnose minnow	150	0.33
Bigeye chub	48	0.11
Golden redhorse	7	4.45
Black redhorse	4	1.08
Shorthead redhorse	1	0.45
White sucker	1	0.79
Quillback	1	1.40
Channel catfish	28	7.82
Flathead catfish	21	0.35
Trout-perch	33	0.17
Pumpkinseed	2	0.02
Bluegill	5	0.02
Rock bass	10	0.72
Smallmouth bass	6	0.46
Black crappie	5	0.13
Logperch	4	0.05
Johnny darter	3	0.02
Yellow perch	1	0.02
Walleye	4	0.76
TOTAL - 23 species	22,133	68.90

OHIO RIVER

New Cumberland Lock & Dam, M. P. 54.4

September 24, 1968

Species	Number	Weight (lbs.)
Gizzard shad	85	9.17
Carp	410	264.80
Emerald shiner	503	3.27
Spotfin shiner	4	0.03
Sand shiner	65	0.13
Bluntnose minnow	36	0.12
White sucker	3	0.74
Yellow bullhead	30	9.04
Brown bullhead	1364	43.73
White catfish	6	0.13
Channel catfish	477	20.12
Banded killifish	1	0.01
Pumpkinseed	1	0.03
Bluegill	18	0.17
Green sunfish	6	0.10
Warmouth	1	0.01
Largemouth bass	8	1.61
Black crappie	53	3.70
White crappie	1	0.01
Drum	1	2.92
TOTAL - 20 species	3073	359.84

OHIO RIVER

Pike Island Lock & Dam, M. P. 84.3

September 25, 1968

Species	Number	Weight (lbs.)
Gizzard shad	178	19.90
Carp	540	278.26
Goldfish	1	0.50
Emerald shiner	28	0.20
Spotfin shiner	161	0.80
Mimic shiner	451	0.99
Sand shiner	1	0.01
Bluntnose minnow	129	0.44
Silver chub	1	0.01
Creek chub	1	0.01
Golden shiner	5	0.33
Yellow bullhead	10	1.67
Brown bullhead	687	56.74
Channel catfish	793	19.87
Pumpkinseed	15	0.76
Bluegill	31	1.23
Orangespotted sunfish	1	0.02
Green sunfish	8	0.42
Longear sunfish	1	0.17
Rock bass	1	0.01
Largemouth bass	11	7.32
Spotted bass	4	1.52
Black crappie	16	1.24
White crappie	2	0.29
Sauger	1	1.88
Walleye	1	2.03
TOTAL - 26 species	3078	396.60

OHIO RIVER

Lock & Dam No. 15, M. P. 129.1

September 26, 1968

Species	Number	Weight (lbs.)
Gizzard shad	105	9.18
Skipjack	1	0.10
Carp	11	11.37
Emerald shiner	6889	23.11
Spotfin shiner	166	0.56
Mimic shiner	1079	3.62
Bluntnose minnow	166	0.56
Silver chub	3	0.11
Quillback	1	0.85
Brown bullhead	9	1.59
Channel catfish	1037	54.07
Pumpkinseed	1	0.08
Bluegill	1	0.05
Green sunfish	32	0.31
Largemouth bass	1	0.04
Spotted bass	58	10.70
Black crappie	1	0.23
White crappie	3	0.89
Drum	1	0.26
Brook silversides	1	0.01
TOTAL - 20 species	9566	117.69

OHIO RIVER

Belleville Lock & Dam, M. P. 204.0

October 1, 1968

Species	Number	Weight (lbs.)
Longnose gar	1	1.62
Gizzard shad	269	10.12
Skipjack	16	2.62
Carp	28	20.23
Emerald shiner	690	2.40
Sand shiner	747	1.24
Ghost shiner	47	0.11
Bluntnose minnow	72	0.16
Silver chub	1	0.01
Black buffalo	2	1.51
River carpsucker	1	1.58
Yellow bullhead	2	1.80
Brown bullhead	884	154.89
Channel catfish	1648	41.08
American eel	2	0.28
Bluegill	11	0.10
Orangespotted sunfish	2	0.01
Redear sunfish	2	0.01
Spotted bass	1	0.44
White crappie	4	0.08
Drum	3	2.34
TOTAL - 21 species	4433	242.63

OHIO RIVER

Lock & Dam No. 23, M. P. 231.4

October 2, 1968

Species	Number	Weight (lbs.)
Gizzard shad	1640	81.15
Skipjack	111	4.55
Carp	22	14.41
Emerald shiner	566	1.40
Ghost shiner	553	0.75
Sand shiner	6	0.02
Mimic shiner	298	0.40
Spotfin shiner	2	0.01
Bluntnose minnow	50	0.12
Smallmouth buffalo	1	3.51
Brown bullhead	6	0.71
Channel catfish	1354	42.51
Flathead catfish	1	0.07
White bass	1	0.28
Largemouth bass	9	5.19
Black crappie	1	0.29
Sauger	2	1.93
Drum	5	1.48
TOTAL - 18 species	4628	158.78

OHIO RIVER

Gallipolis Lock & Dam, M. P. 279.2

October 3, 1968

Species	Number	Weight (lbs.)
Longnose gar	2	0.75
Gizzard shad	123	18.22
Skipjack	309	13.40
Carp	87	146.25
Emerald shiner	587	2.68
Mimic shiner	513	1.77
Ghost shiner	1	0.01
Bluntnose minnow	26	0.05
Silver chub	11	0.11
Smallmouth buffalo	3	2.48
Quillback	1	0.75
Brown bullhead	8	0.86
Channel catfish	1529	51.05
Flathead catfish	1	0.04
American eel	2	0.38
White bass	1	0.14
Bluegill	4	0.36
Redear sunfish	2	0.10
Spotted bass	1	0.42
Largemouth bass	1	0.90
Black crappie	2	1.00
Sauger	3	1.32
Drum	105	9.68
TOTAL - 23 species	3322	252.97

OHIO RIVER

Greenup Lock & Dam, M. P. 341.0

October 8, 1968

Species	Number	Weight (lbs.)
Gizzard shad	562	46.50
Skipjack	25	4.49
Mooneye	2	0.49
Goldeye	1	1.46
Northern pike	1	0.77
Carp	196	75.45
Emerald shiner	90	0.24
Mimic shiner	234	0.34
Ghost shiner	1	0.01
Silver chub	9	0.22
Quillback	2	0.51
Brown bullhead	8	1.81
Channel catfish	363	75.21
Flathead catfish	1	5.70
Green sunfish	1	0.04
Redear sunfish	1	0.01
Bluegill	11	1.20
Spotted bass	2	0.83
Black crappie	42	4.24
White crappie	8	3.33
Sauger	33	13.14
Drum	61	15.52
TOTAL - 22 species	1654	251.51

OHIO RIVER

Meldahl Lock & Dam, M. P. 436.4

October 9, 1968

Species	Number	Weight (lbs.)
Longnose gar	5	3.58
Gizzard shad	1163	76.84
Skipjack	37	8.28
Goldeye	1	0.32
Carp	146	286.10
Emerald shiner	49	0.12
Mimic shiner	55	0.07
Ghost shiner	1	0.01
Silver chub	3	0.03
Black buffalo	1	2.80
Smallmouth buffalo	5	7.30
Quillback	3	3.23
Golden redhorse	4	4.64
River carpsucker	1	1.03
Brown bullhead	10	0.40
Channel catfish	260	91.44
Flathead catfish	2	0.01
American eel	1	0.36
White bass	2	0.71
Bluegill	32	2.22
Green sunfish	1	0.01
Spotted bass	2	0.94
Black crappie	20	3.48
White crappie	38	0.79
Logperch	2	0.05
Sauger	27	10.86
Drum	81	56.81
TOTAL - 27 species	1952	562.43

OHIO RIVER

Markland Lock & Dam, M. P. 531.5

September 10, 1968

Species	Number	Weight (lbs.)
Longnose gar	7	1.40
Skipjack herring	400	4.20
Gizzard shad	1,942	416.85
Threadfin shad	1	0.01
Carp	190	450.90
Goldfish	12	8.40
Emerald shiner	101	0.13
Silver chub	9	0.01
River carpsucker	2	2.00
Smallmouth buffalo	11	21.90
Spotted sucker	1	1.10
Yellow bullhead	6	0.10
Black bullhead	3	0.01
Channel catfish	235	120.10
Blue catfish	1	0.01
Flathead catfish	6	1.80
American eel	37	6.60
Bluegill	24	2.50
White crappie	1	0.01
Black crappie	1	0.20
Walleye	2	0.50
Freshwater drum	121	22.86
TOTAL - 22 species	3,155	1,057.29

OHIO RIVER

McAlpine Lock & Dam, M. P. 607.0

September 11, 1968

Species	Number	Weight (lbs.)
Longnose gar	4	4.60
Skipjack herring	25	1.83
Gizzard shad	407	80.30
Carp	10	31.80
Emerald shiner	157	0.30
Silver chub	4	0.02
Highfin carpsucker	2	1.80
Smallmouth buffalo	1	2.25
Channel catfish	83	33.21
Flathead catfish	4	0.33
Bluegill	18	0.10
Spotted bass	2	0.20
White crappie	8	1.81
Black crappie	1	0.01
Walleye	1	0.33
Freshwater drum	70	18.92
TOTAL - 16 species	797	177.81

OHIO RIVER

Lock & Dam No. 43, M. P. 633.2

September 12, 1968

Species	Number	Weight (lbs.)
Skipjack herring	16	0.15
Gizzard shad	24	6.00
Carp	1	0.60
Silver chub	4	0.01
Highfin carpsucker	2	2.70
Smallmouth buffalo	13	19.30
River redhorse	1	1.30
Channel catfish	76	23.32
Flathead catfish	2	0.01
Bluegill	1	0.09
Longear sunfish	1	0.15
Sauger	4	1.85
Freshwater drum	36	18.27
TOTAL - 13 species	197	73.73

OHIO RIVER

Cannelton Lock & Dam, M. P. 720.7

September 17, 1968

Species	Number	Weight (lbs.)
Longnose gar	6	1.60
Bowfin	1	6.40
Skipjack herring	272	3.40
Gizzard shad	37	8.55
Threadfin shad	4	0.40
Goldeye	2	0.50
Mooneye	3	0.70
Carp	35	91.50
Golden shiner	1	0.10
Emerald shiner	142	0.38
River shiner	20	0.06
Silver chub	109	0.12
River carpsucker	11	13.30
Quillback	1	0.30
Smallmouth buffalo	6	2.10
Bigmouth buffalo	4	5.65
Spotted sucker	1	0.30
Black bullhead	1	0.01
Channel catfish	143	20.21
Blue catfish	55	5.35
Flathead catfish	6	5.00
Warmouth	1	0.25
Green sunfish	8	0.67
Bluegill	116	10.20
Longear sunfish	3	0.25
Redear sunfish	2	0.65
Spotted bass	7	2.35
Largemouth bass	4	4.10
White crappie	56	16.90
Black crappie	9	2.50
Sauger	1	1.40
Freshwater drum	305	34.30
TOTAL - 32 species	1372	239.49

OHIO RIVER

Lock & Dam No. 47, M. P. 777.7

September 18, 1968

Species	Number	Weight (lbs.)
Skipjack herring	23	3.46
Gizzard shad	17	5.34
Goldeye	2	1.10
Carp	3	3.10
Silver chub	2	0.01
Emerald shiner	268	3.10
Mimic shiner	35	0.10
Rosyface shiner	1	0.01
Quillback	4	1.90
Smallmouth buffalo	16	9.85
Black buffalo	1	0.40
River carpsucker	1	2.10
Channel catfish	152	31.85
Flathead catfish	5	0.01
Bluegill	1	0.10
Longear sunfish	2	0.30
Spotted bass	1	0.01
White crappie	1	0.15
White bass	1	0.20
Yellow bass	1	0.20
Freshwater drum	415	137.70
TOTAL - 21 species	952	200.99

OHIO RIVER

Lock & Dam No. 50 (embayment), M. P. 876.8

August 21, 1968

Species	Number	Weight (lbs.)
Shortnose gar	3	0.25
Skipjack herring	3	0.25
Gizzard shad	12,000	2,000.00
Carp	43	110.30
Emerald shiner	1	0.01
Silver chub	1	0.01
River carpsucker	16	12.40
Quillback	24	7.50
Highfin carpsucker	17	9.50
Smallmouth buffalo	13	16.30
Bigmouth buffalo	34	153.70
Spotted sucker	15	8.40
Golden redhorse	1	0.20
Yellow bullhead	2	0.60
Black bullhead	6	1.30
Channel catfish	66	73.30
Flathead catfish	12	0.01
White bass	1	0.40
Yellow bass	3	0.41
Green sunfish	4	0.40
Orange-spotted sunfish	1	0.08
Bluegill	16	2.81
Longear sunfish	22	1.05
Redear sunfish	1	0.01
Spotted bass	3	0.20
Largemouth bass	7	13.00
White crappie	390	11.25
Black crappie	224	14.07
Warmouth	48	3.60
Rock bass	6	0.26
Pirate perch	31	0.21
Sauger	68	3.80
Freshwater drum	349	27.80
TOTAL - 33 species	13,431	2,473.36

DERIVATION OF AQUATIC LIFE REQUIREMENTS FOR THE TEMPERATURE CHARACTERISTIC

Donald I. Mount, Ph.D.

AQUATIC LIFE TEMPERATURE CRITERIA

CLASS I -- WARM WATER BIOTA

SPECIES -- Largemouth Bass
Smallmouth Bass
White Bass
Sauger
Channel Catfish
Emerald Shiner
Freshwater Drum
Golden Redhorse
Buffalo
White Sucker
Fathead Minnow

	Period Mean, ^{o}F.	Hourly Max., ^{o}F.
December-February	48	55
March 1-15	50	56
March 16-31	52	58
April 1-15	55	60
April 16-30	58	62
May 1-15	62	64
May 16-31	68	72
June 1-15	75	79
July-September	82	86
October	75	82
November	65	72

AQUATIC LIFE TEMPERATURE CRITERIA

CLASS II -- WARM WATER BIOTA

SPECIES -- Largemouth Bass
Smallmouth Bass
White Bass
Channel Catfish
Emerald Shiner
Freshwater Drum
Golden Redhorse
Buffalo
White Sucker
Fathead Minnow

	Period Mean, °F.	Hourly Max., °F.
December	55	60
January	48	55
February	48	55
March 1-15	52	58
March 16-31	58	64
April 1-15	64	70
April 16-30	68	72
May 1-15	70	74
May 16-31	74	78
June 1-15	78	82
June 16-30	82	85
July	84	86
August	84	86
September	84	86
October	75	82
November	65	72

AQUATIC LIFE TEMPERATURE CRITERIA

CLASS III -- WARM WATER BIOTA

SPECIES -- Largemouth Bass
White Bass
Channel Catfish
Freshwater Drum
Buffalo
Fathead Minnow

	Period Mean, ^{o}F.	Hourly Max., ^{o}F.	96-Hr.TL_m, ^{o}F.*
December	55	60	60
January	50	55	55
February	50	55	55
March 1-15	55	60	60
March 16-31	60	65	65
April 1-15	65	70	77
April 16-30	70	75	80
May 1-15	70	75	83
May 16-31	82	86	90
June 1-15	78	82	86
June 16-30	82	86	92
July	86	90	92
August	86	90	90
September	86	90	90
October	75	82	82
November	65	72	72

*96-Hr. TL_m, ^{o}F. -- denotes maximum temperatures that should be allowed in mixing zone so 50 per cent of the specified fish population would survive in a 96-hour period.

AQUATIC LIFE TEMPERATURE CRITERIA

CLASS A -- COLD WATER BIOTA

SPECIES -- BROOK, BROWN & RAINBOW TROUT

(WITH REPRODUCTION)

	Period Mean, ^{o}F.	Hourly Max., ^{o}F.	96-Hr.TL_m, ^{o}F.*
December	50	55	64
January	50	55	64
February	50	55	64
March 1-15	50	55	64
March 16-31	50	55	64
April 1-15	50	55	66
April 16-30	50	55	66
May 1-15	54	58	70
May 16-31	58	62	70
June 1-15	62	66	75
June 16-30	67	70	77
July	67	70	77
August	67	70	77
September	58	62	77
October	50	55	64
November	50	55	64

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*96-Hr. TL_m, ^{o}F. -- denotes maximum temperatures that should be allowed in mixing zone so 50 per cent of the specified fish population would survive in a 96-hour period.

AQUATIC LIFE TEMPERATURE CRITERIA

CLASS B -- COLD WATER BIOTA

(PUT AND TAKE TROUT STREAMS)

SPECIES -- BROOK, BROWN & RAINBOW TROUT

(WITHOUT REPRODUCTION)

	Period Mean, ^{o}F.	Hourly Max., ^{o}F.	96-Hr.TL_m, ^{o}F.*
December	55	60	64
January	50	55	64
February	50	55	64
March 1-15	55	60	64
March 16-31	55	60	64
April 1-15	60	65	66
April 16-30	60	65	66
May 1-15	60	65	70
May 16-31	66	70	70
June	66	70	75
July	66	70	77
August	66	70	77
September	66	70	77
October	60	65	70
November	55	60	64

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*96-Hr. TL_m, ^{o}F. -- denotes maximum temperatures that should be allowed in mixing zone so 50 per cent of the specified fish population would survive in a 96-hour period.